National Defense Center for Energy and Environment

BIODIESEL: PAVING THE WAY FOR DOD'S RENEWABLE FUTURE:

David Chavez, NAVFAC ESC

5/11/2011

DoD Executive Agent

Office of the Assistant Secretary of the Army Installations, Energy and Environment

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NDCEE Task 0555 in support of:

ESTCP WP-0728

Demonstration of Biodiesel Blend Use in Ground Tactical Vehicles and Equipment (non-deployed)

Mr. David Chavez

NAVFAC Engineering Service Center

Additional Project Support

- **Navy's Environmental Sustainability Development to Integration (NESDI) program**
- **Joint Group on Pollution Prevention (JG-PP)**

Project Team

- **Principal Investigator**
  - Dave Chavez, Naval Facilities Engineering Service Center (NFESC)
- **Tri-Service Petroleum, Oil, and Lubricant Working Group**
  - Luis Villahermosa, TARDEC, Army Team Leader, Subject Matter Expert (SME)
  - Richard Kamin, CNO, Navy Tactical Energy
  - Ben Curtis, Air Force Petroleum Agency
- **Field, Laboratory, and SME Support**
  - Bill Black, Marine Corps Light Armored Vehicle (LAV) Office
  - Sherry Williams, Navy Fuels and Lubricants Cross Functional Team
  - Emilio Alfaro, AFPET
  - George Handy, NDCEE/CTC
  - Kevin Merichko, NDCEE/CTC
  - Leanne Debias, NDCEE/CTC
  - Steven Westbrook, Southwest Research Institute (SwRI)
- **Additional DoD and Industry Support**
  - Omar Mendoza, Air Force Research Laboratory
  - Steve Howell, National Biodiesel Board
  - Robert McCormick, PhD, National Renewable Energy Laboratory

Technical Objectives

- The objective is to demonstrate and validate the use of B20 in non-deployed ground tactical vehicles and equipment by addressing users concerns:

1. Stability of the biodiesel
2. Accelerated deterioration during high temperature storage
3. Vehicle operation and fuel properties in low temperatures
4. Water affinity and microbial degradation
5. Material compatibility and solvency

Technical Approach

- Demonstrated biodiesel blend (B20) in non-deployed tactical vehicles and equipment for various operational schedules and climate conditions to address user concerns

Demonstration Sites:

- NSWC Crane, IN (Hot/Cold, Humid)
  - User Concern #1 thru #5
  - LAV, Operated 4 hours/Month
  - LAV, Operated 15 Min/Month
- 29 Palms, CA (Hot, Dry)
  - User Concern #1, #2, #4 and #5
  - HMMWV (HUMVEE), Operated once every 4 weeks

Technical Approach

Demonstration Sites:

- Moody AFB, GA (Hot, Humid Climate)
  - User Concern #1, #2, #4 and #5
  - Older Model Bobtails (1997 Dodge)
  - Newer Model Bobtails (2008 Dodge)
  - Refueler Truck
- NBVC, CA (Mild Climate)
  - User Concern #1, #4 and #5
  - MTVR, Operated as a part of Seabee Training Schedule
- MCBH, HI (Hot, Humid Climate)
  - User Concern #1, #2, #4 and #5
  - HUMVEE
  - TRAM

Overview of Prior Work

- Established DoD Team
  - Subject Matter Experts from Army, Navy, and Air Force
- Gained DoD Sites and Vehicles for Demonstration
- Developed Demonstration Plan
- Established Laboratory Fuel Analysis Contract
- Began Collecting Data at 4 DoD Sites:
  - 29 Palms – July 2009
  - NSWC Crane – August 2009
  - Moody – Sept 2009
  - NBVC – July 2009 (Restarted January 2010)

Overview of Prior Work

- Added MCBH to site installations and began collecting data (June 2010):
  - TRAM
  - HUMVEE

- Completed data collection at 5 DoD sites (12/2010)
- Completed engine oil and fuel testing (1/2011)
- Performing trend analysis

Methodology

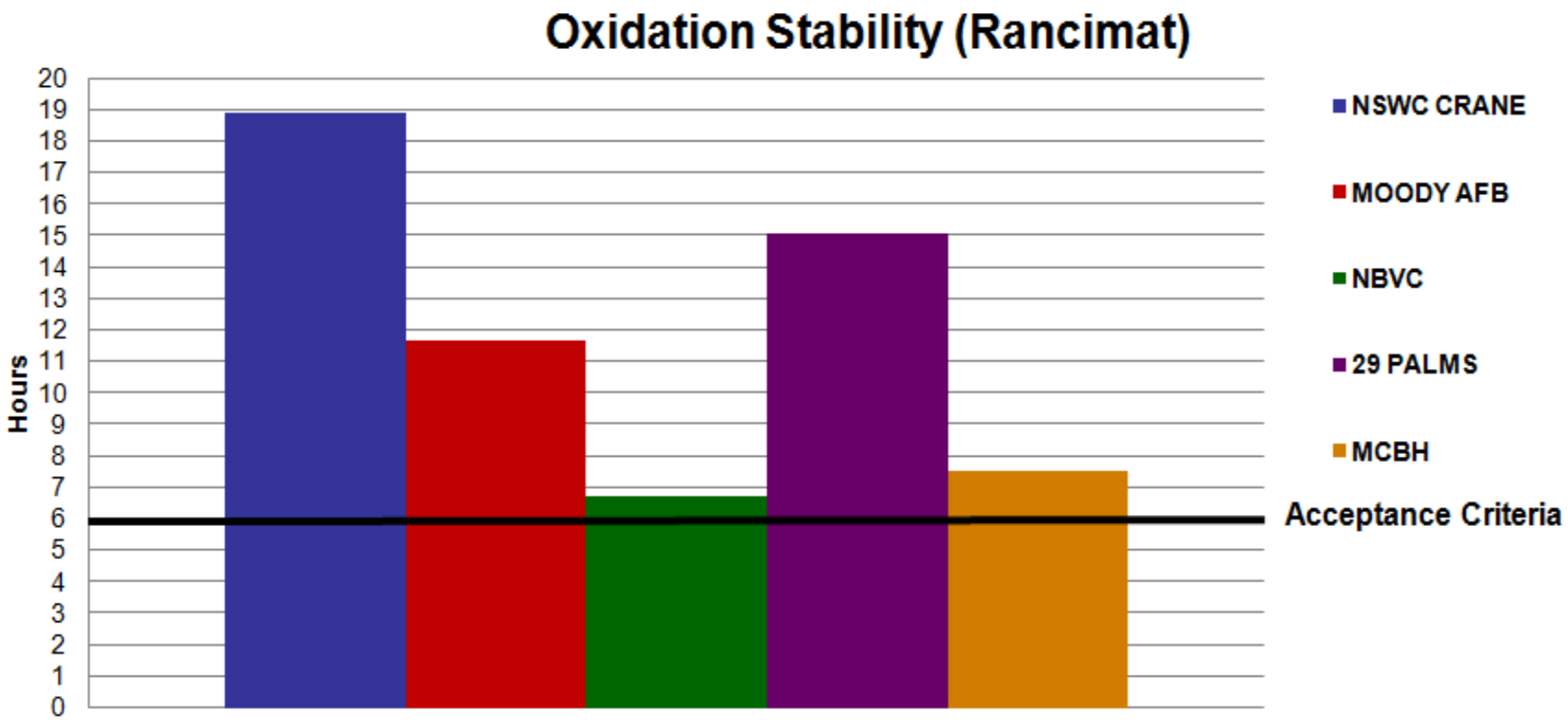
- Engine oil samples submitted to TARDEC for analysis (monthly).

- The oil testing methods are based upon the methodology contained in the JOAP Manual.
  - Wear Metals
  - Total Acid Number
  - Total Base Number
  - Kinematic Viscosity at 40◦C
  - Kinematic Viscosity at 100◦C
  - Viscosity Index
  - Soot Content
  - Percent Fuel Dilution
  - Water Content

Methodology

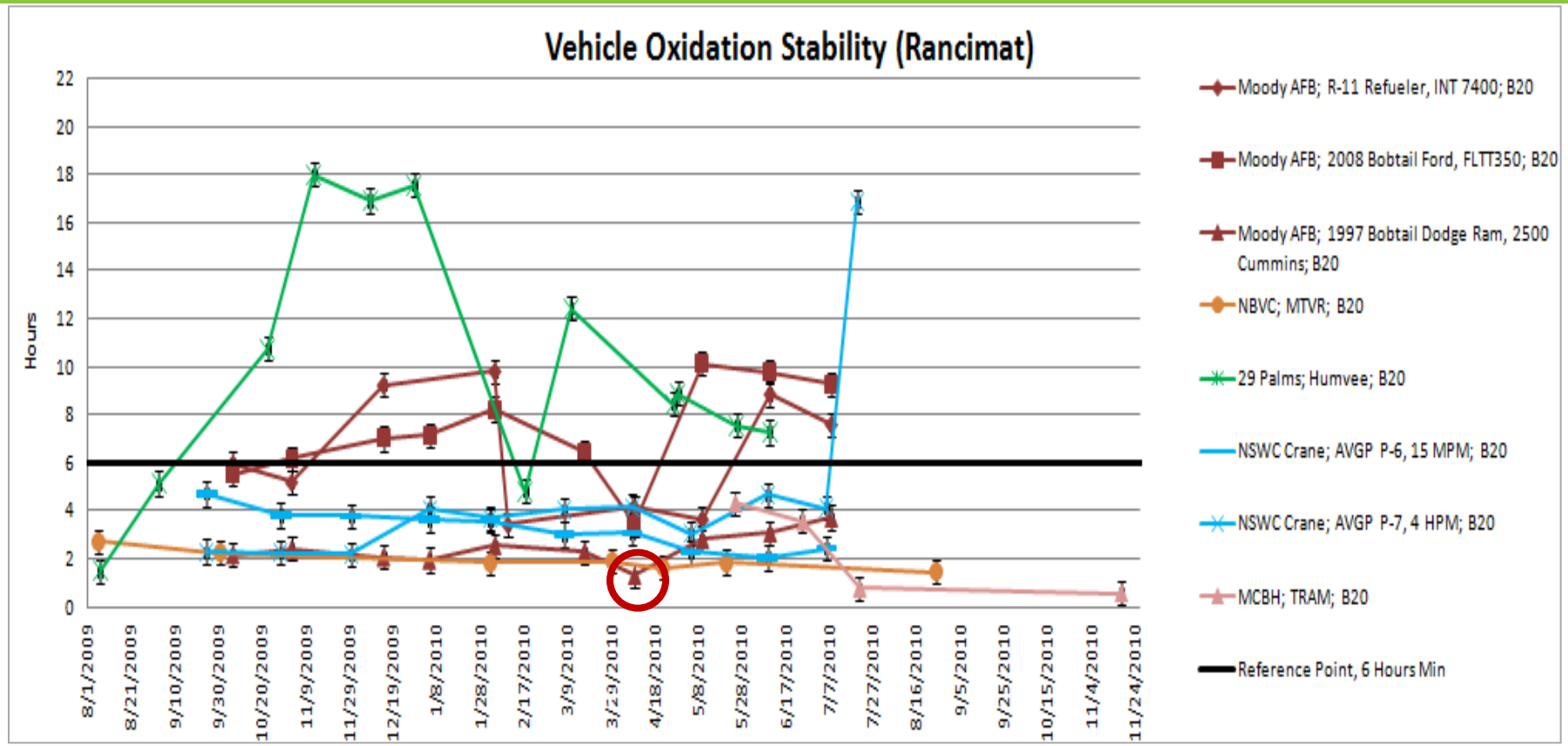
- B20 Vehicle and fuel storage tank (dispenser) samples submitted to *CTC* for analysis (monthly).
- Fuel sample testing and acceptance criteria derived from: B20 specification (A-A-59693A), Navy F-76 specification (MIL-PRF-16884K), and B6-B20 blend specification (ASTM D7467).
  - Appearance
  - Acid Number
  - Viscosity at 40◦C
  - Water & Sediment
  - Total Water Content
  - Color
  - Particulate Contamination
  - Oxidation Stability, Rancimat
  - Stability
    - Total Insolubles
    - Iso-octane Insolubles
    - Acid value

Dispenser
Oxidation Stability - Rancimat



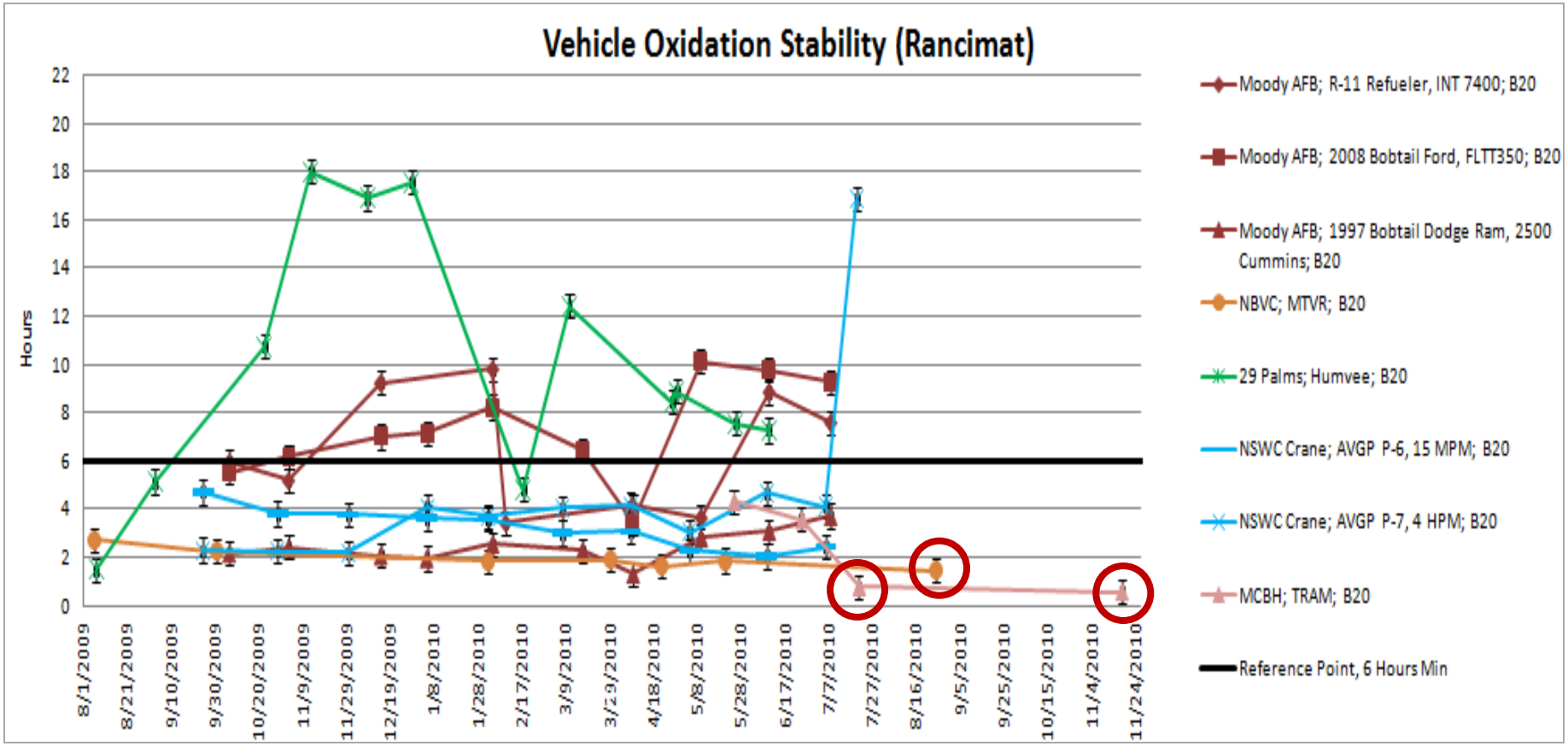
All Initial Fuel Samples Met or Exceeded the Acceptance Criteria.

Vehicle Oxidation Stability - Rancimat



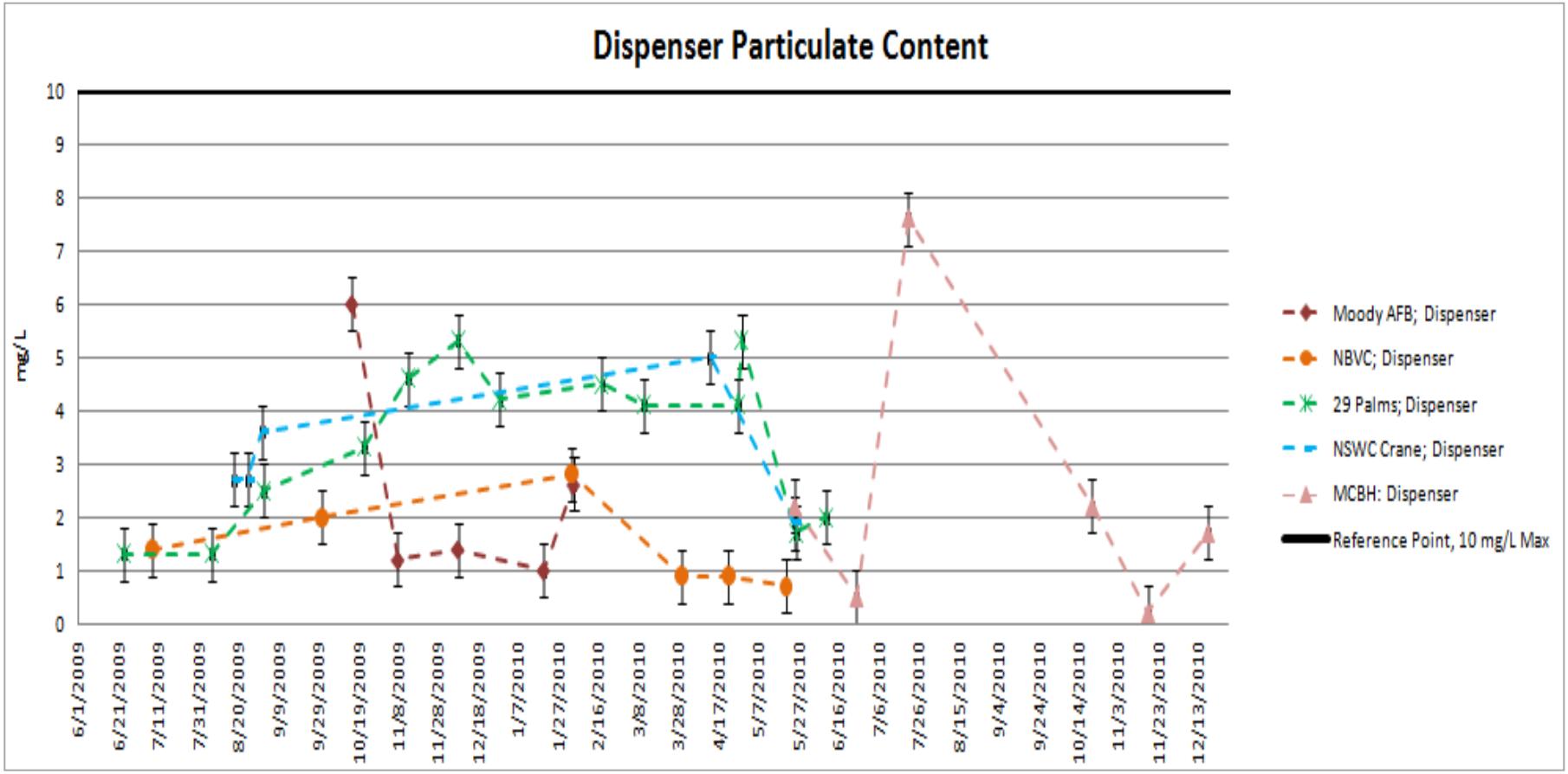
Vehicle sample QA Tests Increased as the vehicles were refueled. Even though the fuel fell below the reference line, vehicle performance remained unchanged. The 1997 Bobtail had a low Rancimat number, 1.3, on 4/9/2010.

Vehicle Oxidation Stability - Rancimat



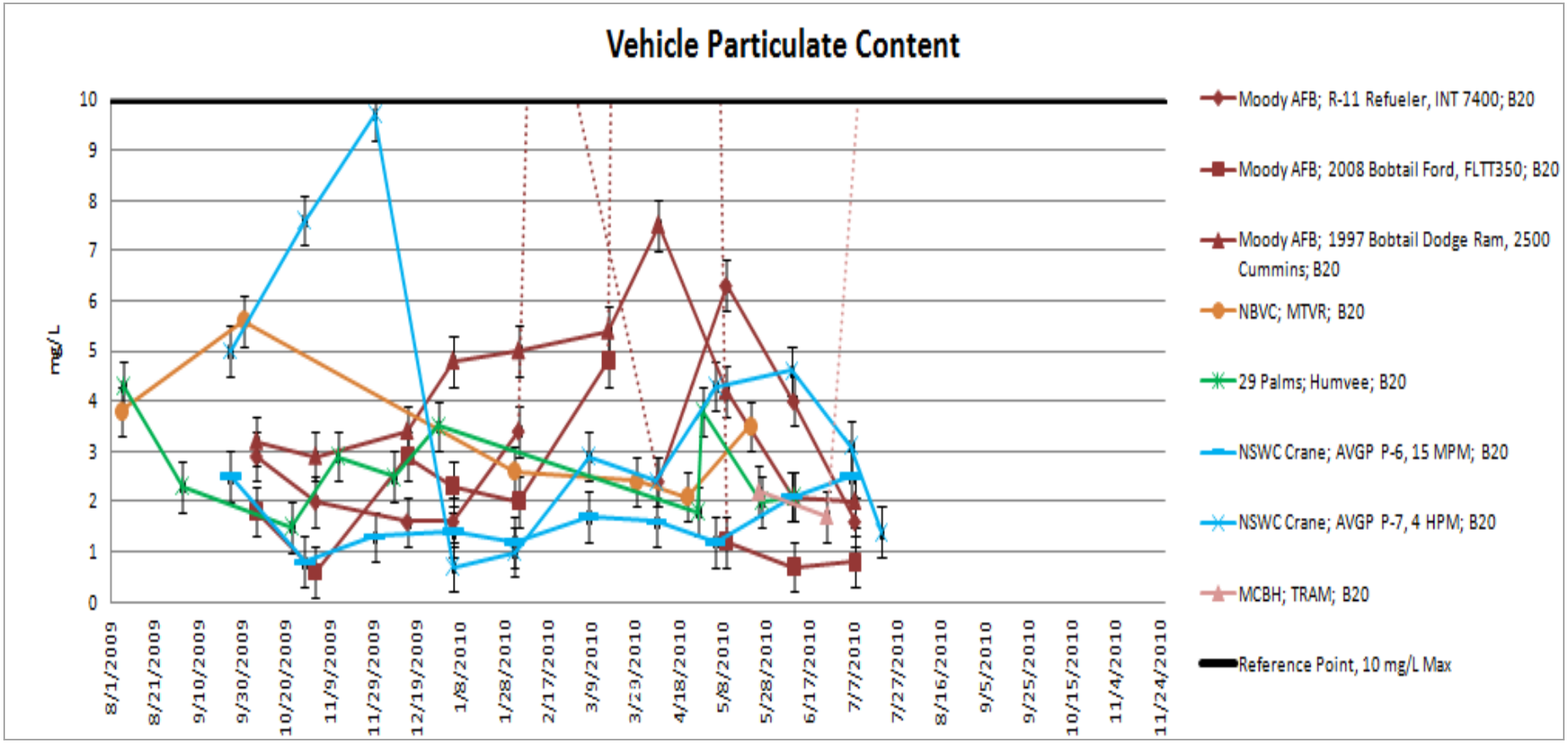
Other Points of Concern at MCBH and NBVC; one time delivery could be the reason for low Rancimat.

Dispenser Particulate Content – ASTM 6217



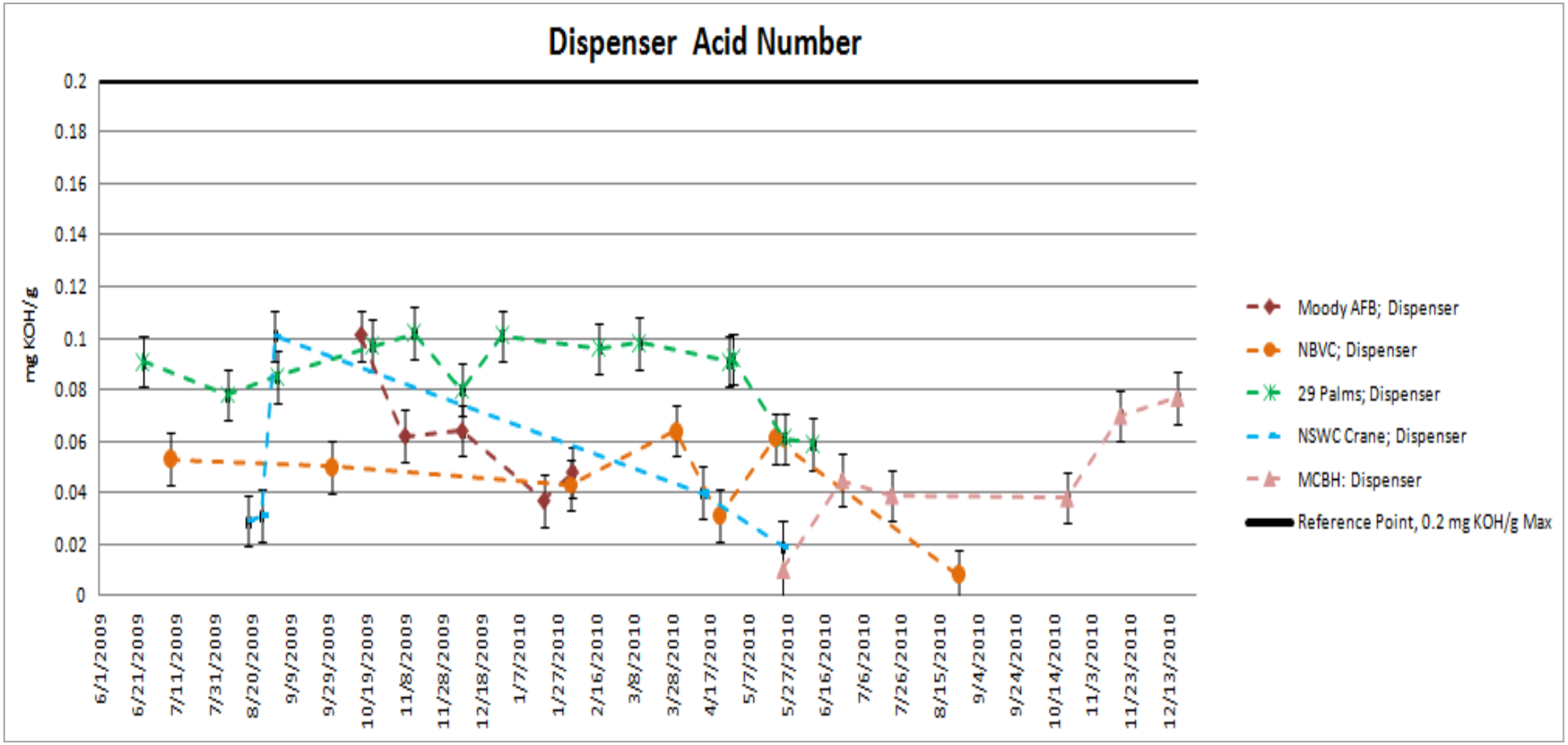
All dispenser samples were well below the reference point.

Vehicle Particulate Content – ASTM 6217



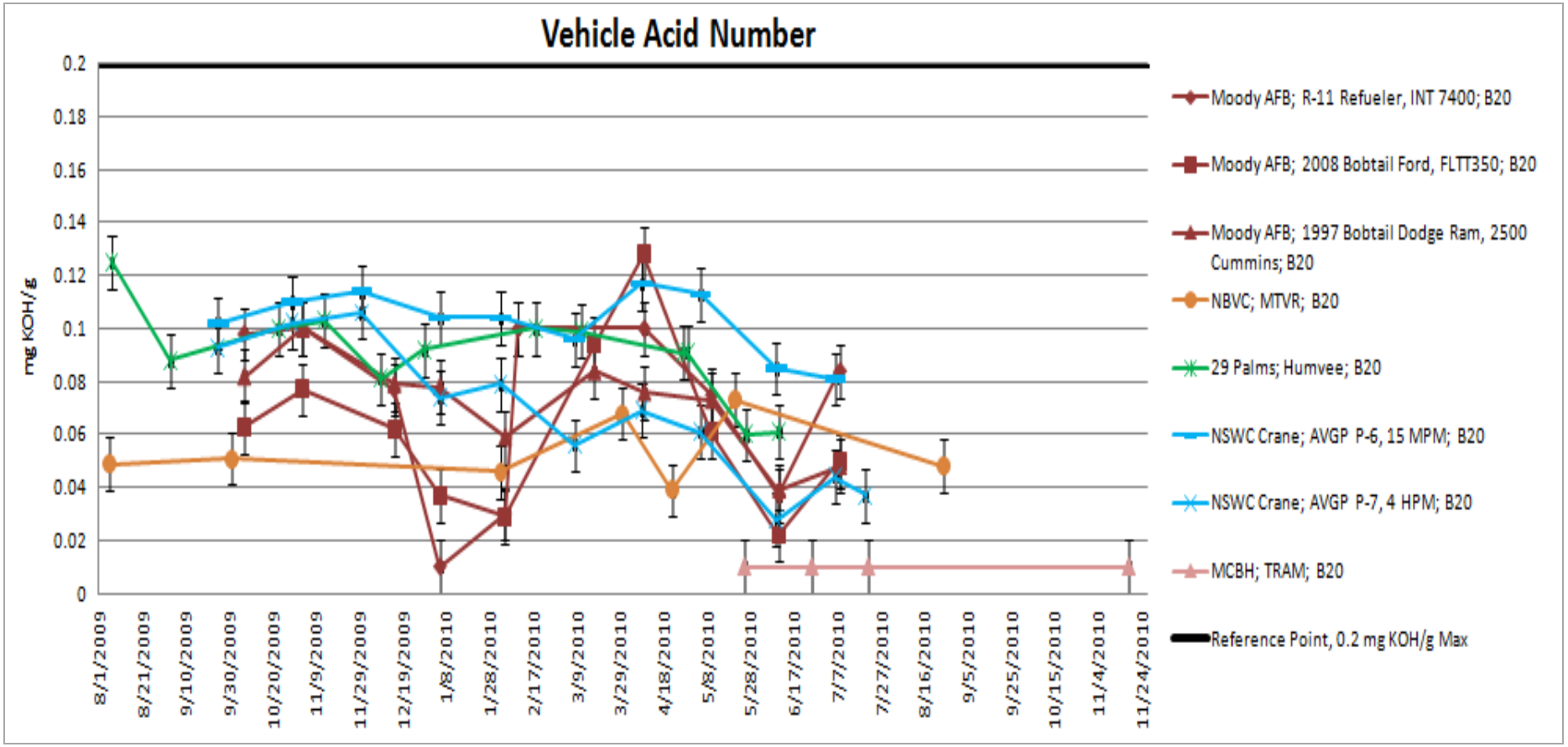
Two Moody AFB vehicles and the MCBH TRAM had incidences where the vehicle samples exceeded the reference points.

Dispenser
Acid Number – ASTM D664



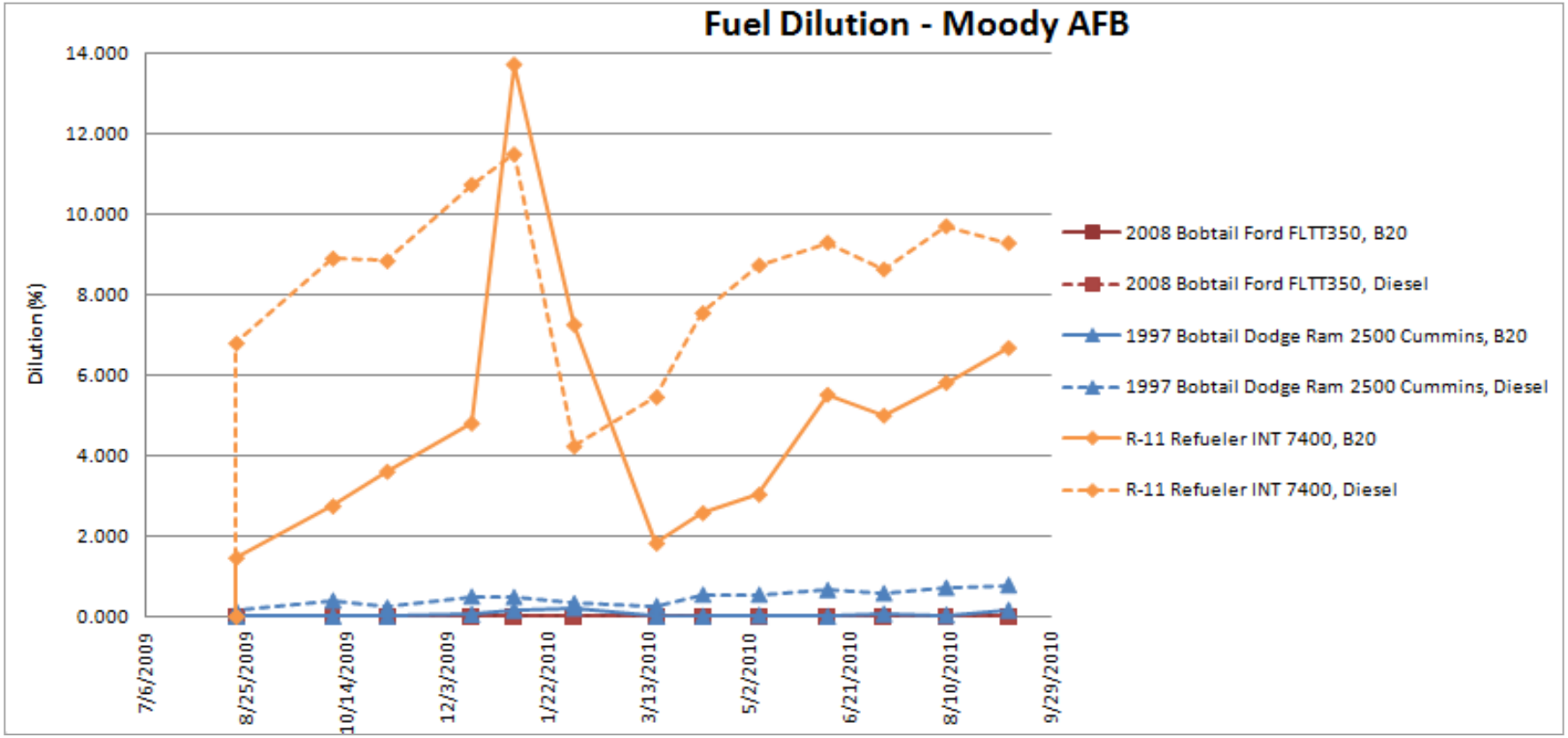
All samples had results less than the reference point of 0.2 mg KOH/g.

Vehicle
Acid Numbers – ASTM D664



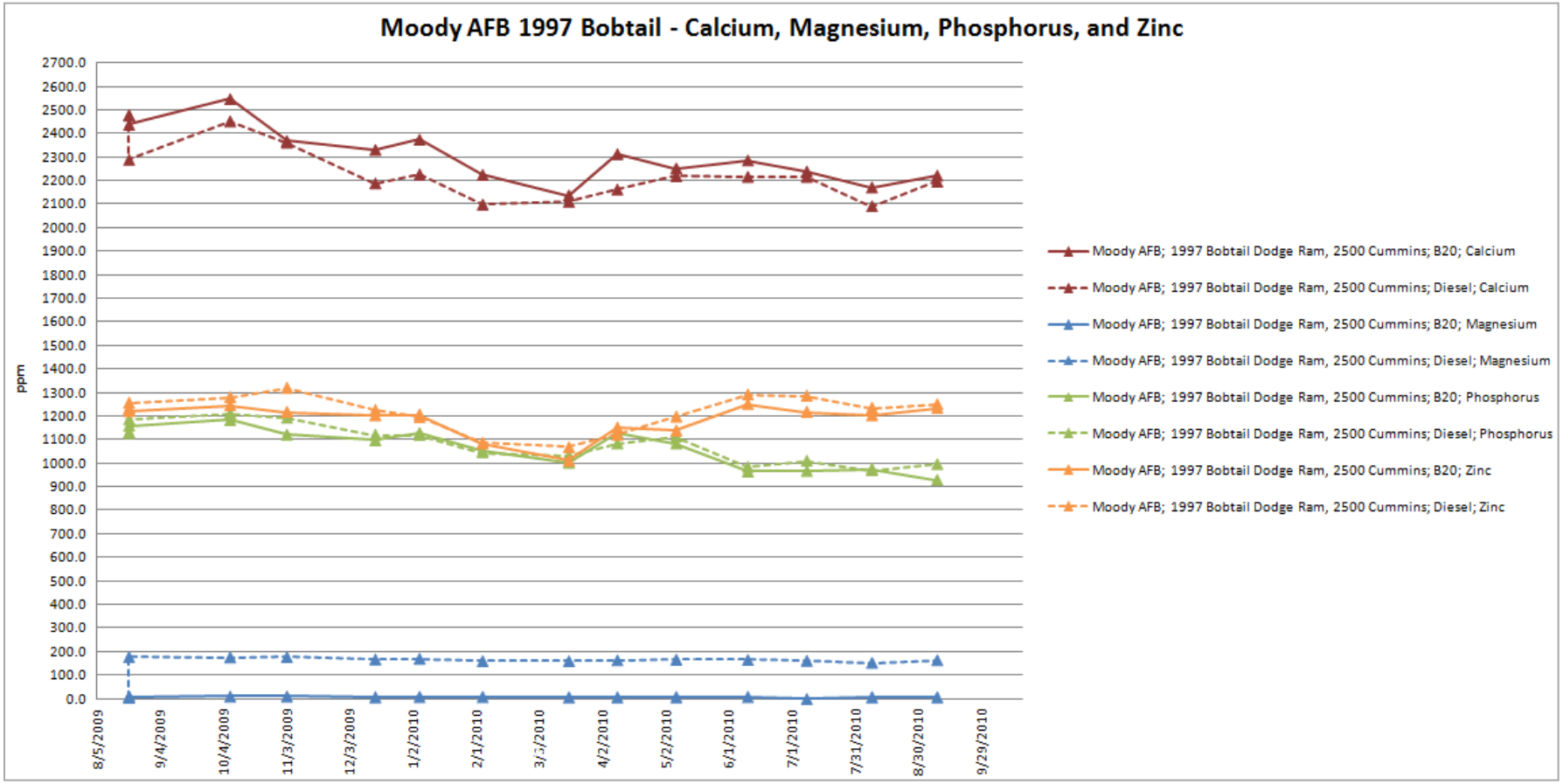
Again, all samples were well below the reference point, having results less than 0.2 mg KOH/g.

JOAP Oil Test Results



No significant difference between test and control vehicles; both Moody Refuelers have fuel infiltration into crank case.

JOAP Oil Test Results



No significant difference between test and control vehicles for JOAP

Vehicle Operator Observations

- Cold Start Issues (User Concern #3: Vehicle operation and fuel properties in low temperatures)
  - 29 Palms (Humvees)
    - Both Test and Control Vehicles have trouble starting after cold nights in desert (14-18 ˚F)
    - Replaced glow plug, that warms fuel prior to start, on both vehicles, cold starting issues have gone away
  - Crane (LAVs)
    - Vehicles smoke initially upon starting in cold weather, but then run normally
      - LAVs have engine pre-heaters to help with starting diesel vehicles in cold weather
      - The control vehicles, running on JP-8, also smoke, just not as long or as much as the test vehicles

Vehicle Operator Observations

- Material Compatibility Issues (User Concern #5, Material Compatibility and Solvency)
  - Moody AFB
    - Fuel sending unit screen separation due to material incompatibility in 1997 Bobtail Truck Fuel Tank
- Fuel Quality Issues (User Concern #1, Stability of the Biodiesel and User Concern #2, Accelerated Deterioration during High Temperature Storage)
  - Moody AFB
    - Orange Deposits in 1997 Bobtail Truck

Vehicle Design Bobtails (from AFPET Study)

- Moody experienced B20 orange residue and maintenance issues in 1997 Bobtail Test Vehicle.
- No B20 residue was seen in the 2008 test vehicle.
- Differences in vehicle design and usage may play a role.
  - Fuel tank covered, less exposed to the sunshine/heat
  - Fuel cap more appropriate and robust
  - Due to recess, less chance of getting water/rain into the fuel tank during refueling
  - Low Usage - 75 hours for the year

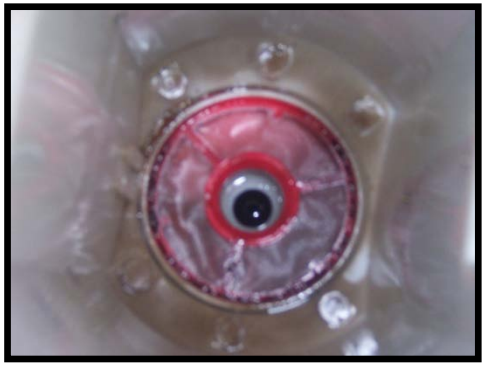
1997

2000

1997 and 2008 Bobtail Fuel System Components

1997 Bobtail (B20)

1997 Bobtail (DF2)



2008 Bobtail B20

Oxidative Stability Deposits at Moody AFB

- Orange deposits found in the Test Vehicle (1997 Bobtail Truck)
  - Deposits found in fuel tanks, fuel sending units, filters, fuel lines, fuel pumps, and other fuel wetted surfaces
  - Vehicle fuel system design a significant factor
    - 2008 Test Vehicle did not have any deposits
  - Caused by low turnover of fuel in vehicle tank, high heat, and humidity.
  - Difficult to clean (somewhat soluble in ethanol)
  - Fuel injector failures very high at this AF Base
  - Material incompatibility causing filter screens to fall out of fuel sending units and into the fuel tanks

Issues

- Fuel Stability Still a Major Concern
  - Moody AFB
- Lack of Maintenance Data
  - Limited number of vehicles
  - Duration of test
- Additional Funding Required to:
  - To Track Fleet of Vehicles Running on B20 (50% Fleet on B20)
  - Increase Variety and Number of Vehicles
  - Collect Statistically Significant Maintenance and Operational Data
  - Provide Periodic Fuel Sampling on Key Indicators
- Marine Corps and Army Interested in Fleet Test
  - MCBH Hawaii and USAG Hawaii

Technology Transfer

- **Path Forward**
  - Develop Final Report with SME input
  - Develop List of Qualified Vehicles and Training Operations with SME input
  - Develop Economic Analysis of using B20 instead of JP-8
  - Larger Number of Vehicles is required to ensure capture of all data
    - B20 related maintenance cost increases
    - Fuel system failures and vehicle break downs
    - Comparison of fuels over preventive maintenance cycles
  - Monitor B20 use under training conditions
    - Interchanging between JP8 and B20
- **Post Project Results**
  - Prior to participation in ESTCP Demonstration access to B20 was limited to test vehicles at MCBH, Base Commander expanded use of B20 to non-tactical fleet and brought on line a 10,000 gal B20 tank.
  - USAG Hawaii currently seeking storage tank to support B20 dispensing

National Defense Center for Energy and Environment

DoD Executive Agent

Office of the Assistant Secretary of the Army Installations, Energy and Environment

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• **NDCEE Alternate Contracting Officer's Representative**	Ms. Darlene Bader-Lohn (IMAE-ETT)
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• **NDCEE Team Members**	Please see Slide 4 "Project Team"

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Questions?

Acronyms and Symbols

- AFPET – Air Force Petroleum Laboratory
- ARFL – Air Force Research Laboratory
- ASN - Assistant Secretary of the Navy
- ASTM – American Society for Testing and Materials
- B20 – Blend of Fuel: 20% biodiesel, 80% petroleum diesel by volume
- B100 – Pure Biodiesel. Biodiesel is defined in ASM D6751 as “a fuel comprised of mono-alkyl esters of long chain fatty acids derived from vegetable oils or animal fats, designated B100.”
- CNO – Chief of Naval Operations
- *CTC* – Current Technologies Corporation
- DENIX – Defense Environmental Network & Information Exchange
- DoD – Department of Defense
- DTIC – Defense Technical Information Network
- EQI – Environmental Quality Initiative
- HMMWV or (Humvees) - High Mobility Multipurpose Wheeled Vehicles
- JOAP – Joint Oil Analysis Program

Acronyms and Symbols

- JTP – Joint Technical Publication
- KOH – Potassium Hydroxide
- LAV – Light Armored Vehicle
- MCBH – Marine Corps Base Hawaii
- MTVR – Medium Tactical Vehicle Replacement or 7-Ton Vehicle
- NBVC – Naval Base Ventura County
- NDCEE – National Defense Center for Energy and Environment
- NESDI – Navy Environmental Sustainability Development to Integration
- NFESC – Naval Facilities Engineering Service Center
- NSWC – Naval Surface Warfare Center
- POL – Petroleum, Oil, and Lubricants
- SME – Subject Matter Expert
- SwRI – Southwest Research Institute
- TARDEC – Tank Automotive Research, Development and Engineering Center
- TRAM - Tractor, Rubber Tired, Articulated Steering, Multi-Purpose

Publications

- **Presentations:**
  - Joint Group on Pollution Prevention, March 10, 2010
  - Joint Group on Pollution Prevention, November 6, 2008
  - National Biodiesel Board Technical Meeting, October 23, 2008
  - Navy Environmental Sustainability Development to Integration Program, June 2, 2008
  - 2nd Annual Alternative Energy NOW Conference, February 21, 2008
  - Joint Group on Pollution Prevention, April 11, 2007

- **Publications:**
  - Navy Environmental Sustainability Development to Integration (NESDI) 2007 Year in Review – Leveraging Resources
  - Currents Magazine Winter 2007 Issue Cover Story - Fueling the Navy in a Petroleum-Challenged World

Methodology

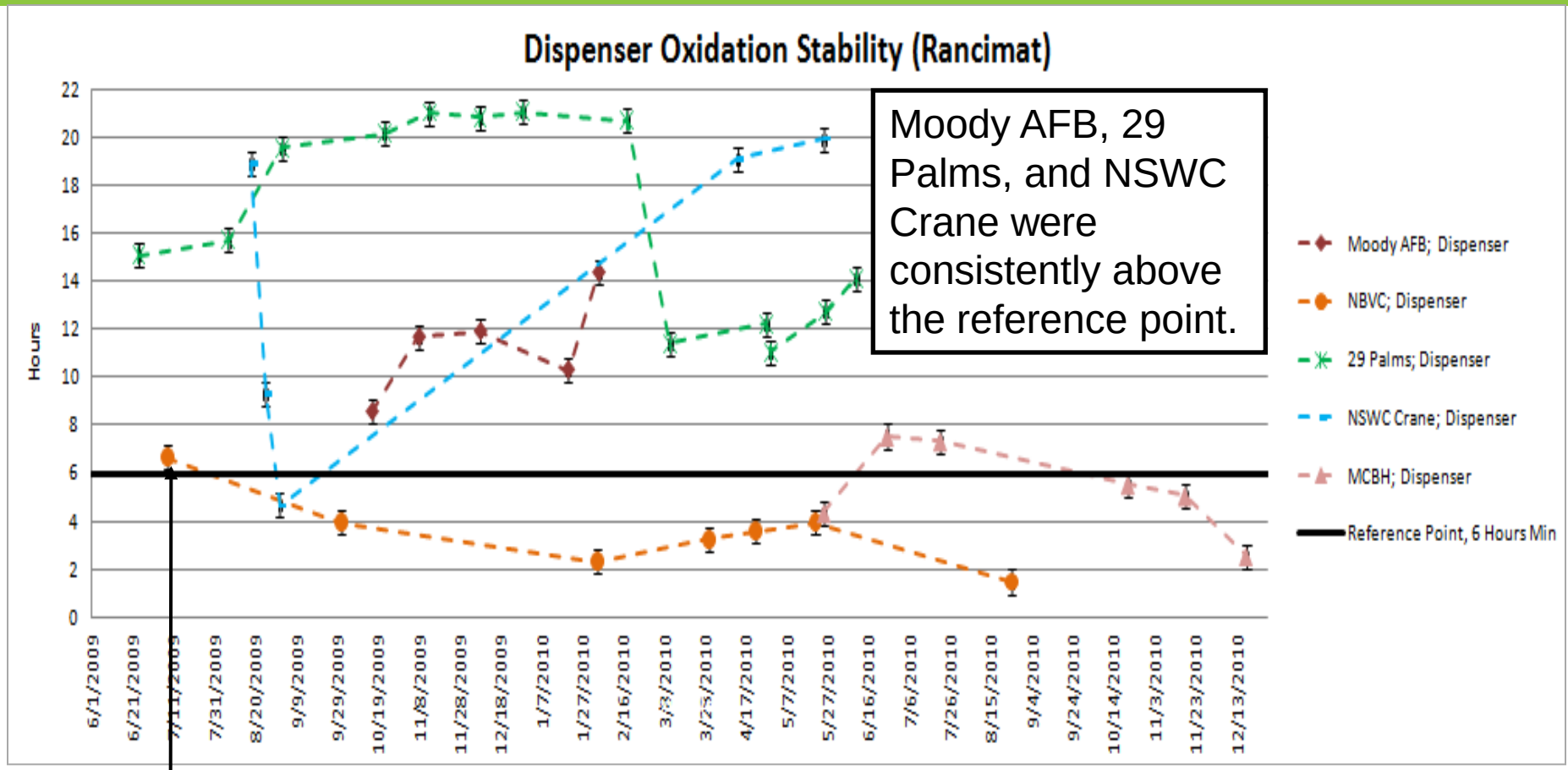
Example Test Methodology: Acid Number
Test Methodology

Parameters	Set an autotitrator to deliver 0.05 mL/min of alcoholic KOH during a potentiometric titration until the potential changes by less than 5 mV/0.1 mL; calculate acid number
Experimental Control	Standardization of KOH, and Titrant blank
Acceptance Criteria	0.2 mg KOH/g, max
Reference Document	ASTM D664

Test Equipment

Lab Equipment Required for Test	Manufacturer	Model #	Serial #
Autotitrator	Brinkmann Instruments/Metrohm USA	836 Titrando	1836002010117
Analytical Balance	A&D	N/A	10400184

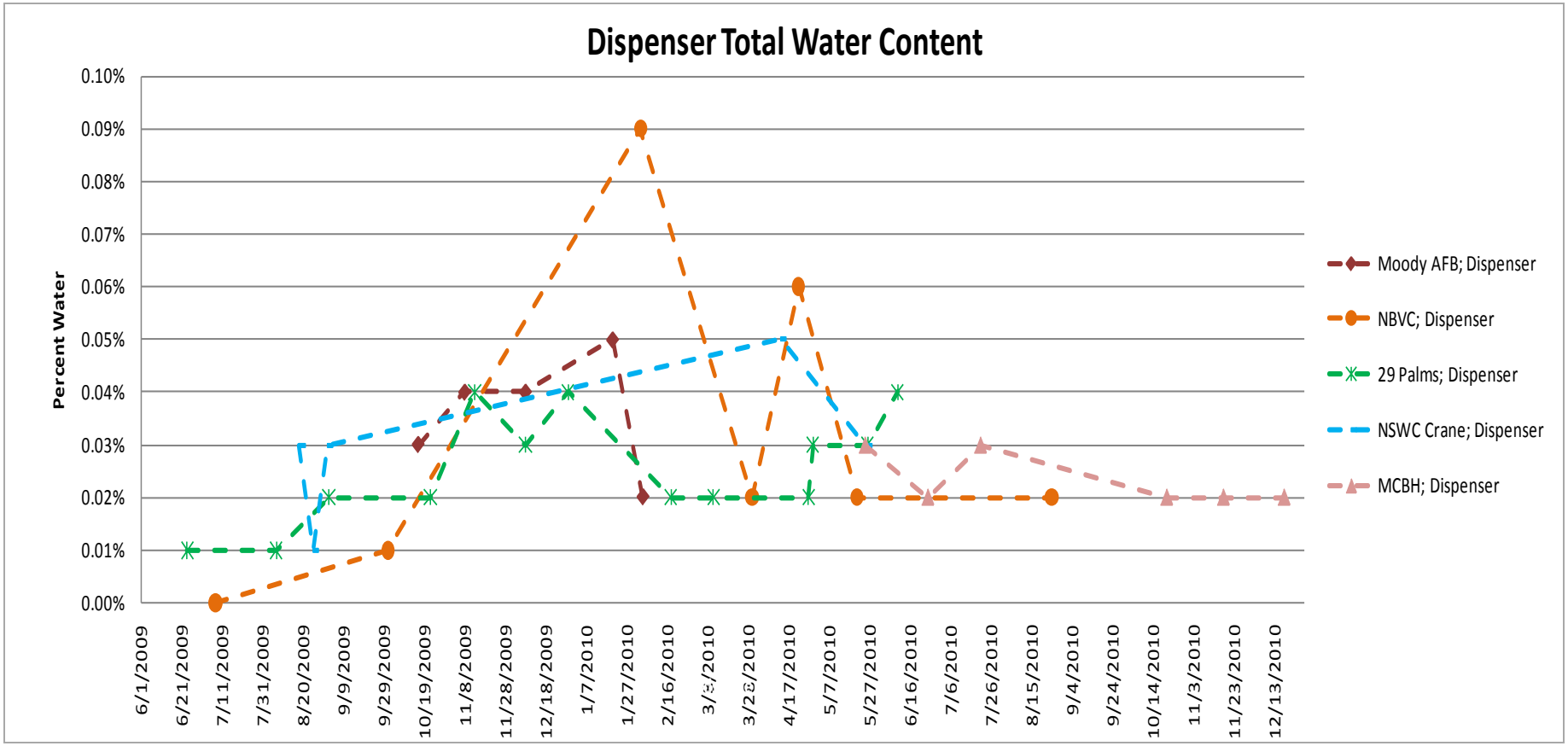
Dispenser
Oxidation Stability - Rancimat



Moody AFB, 29 Palms, and NSWC Crane were consistently above the reference point.

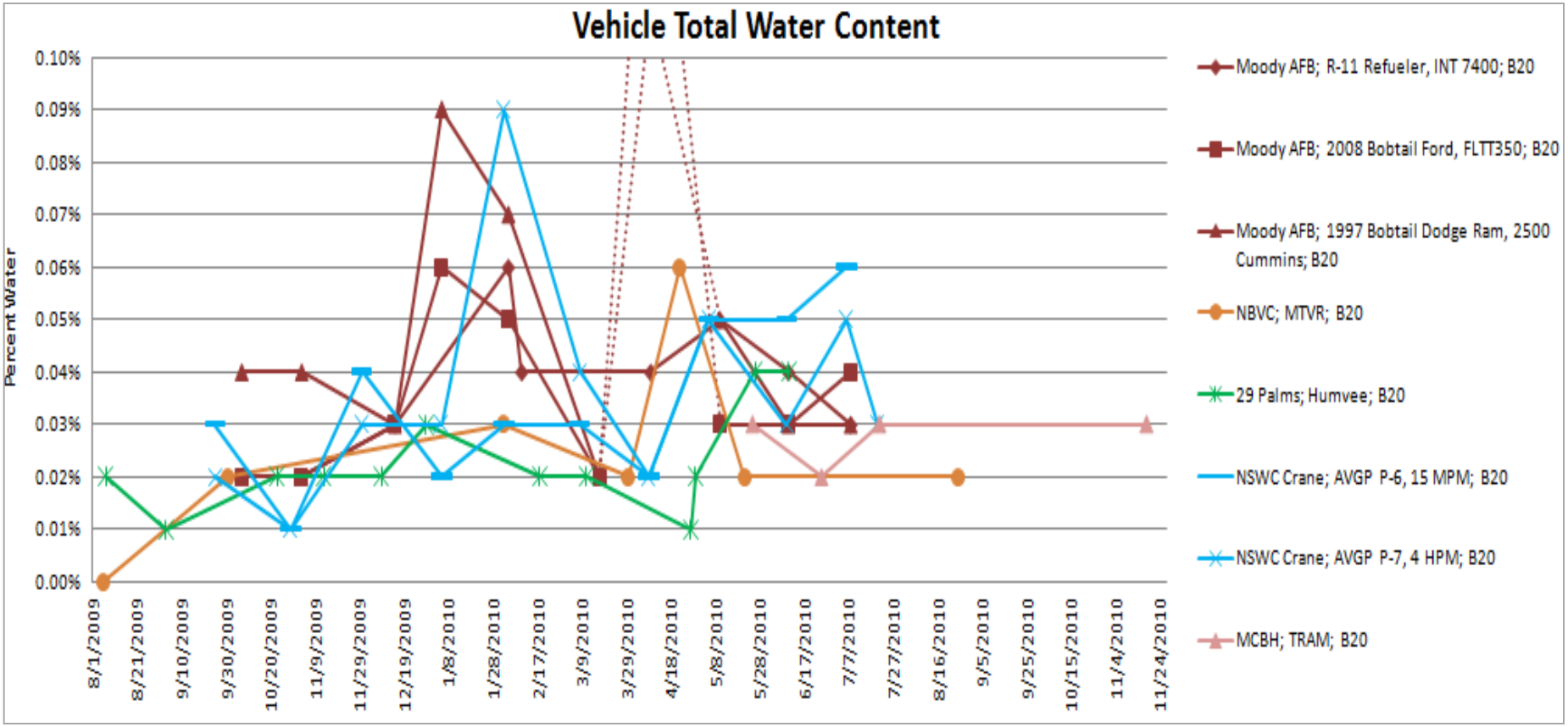
NBVC only exceeded the reference point on the initial sample.

Dispenser
Total Water Content – ASTM D6304



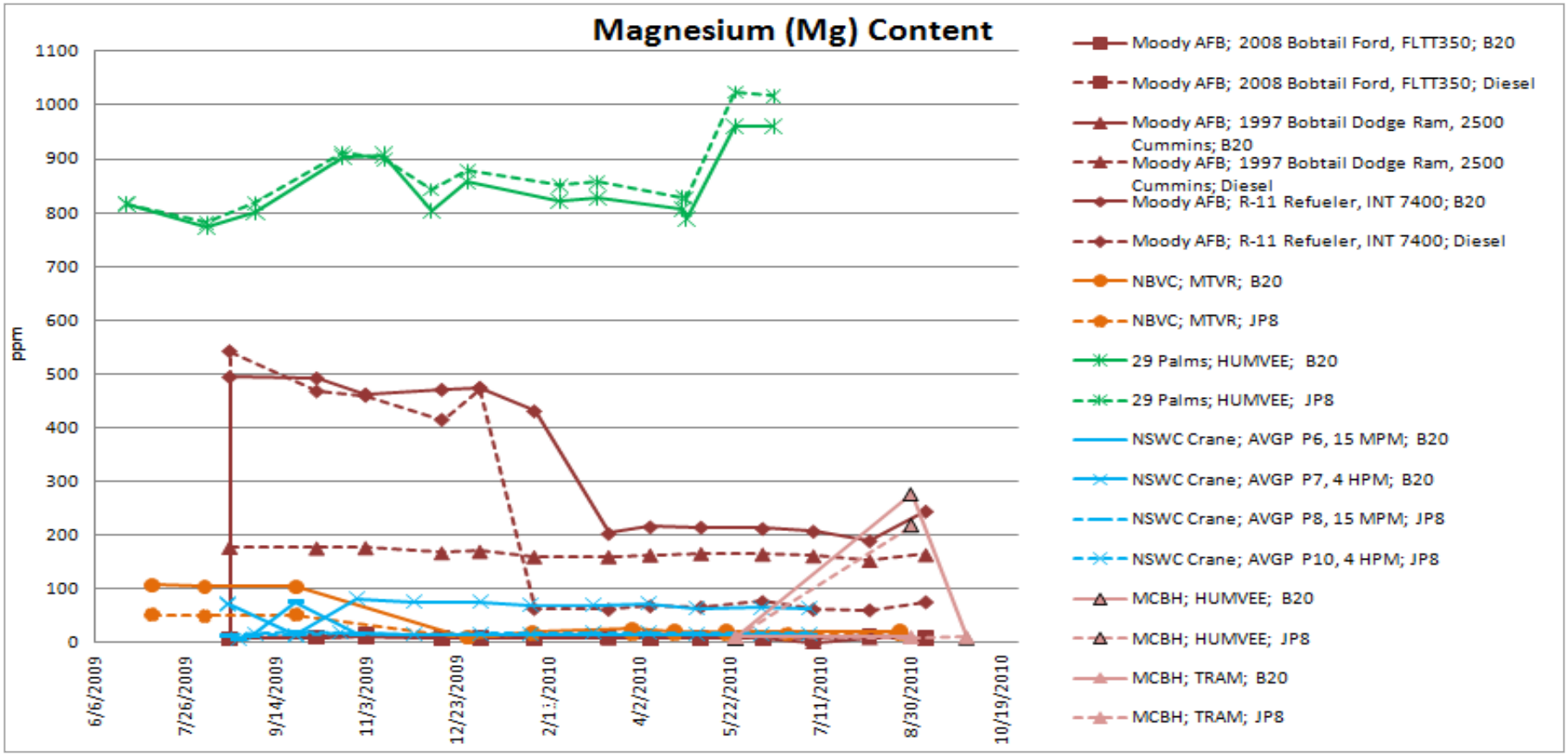
All storage tank samples had water content values well below 0.1%.

Vehicle
Total Water Content – ASTM D6304



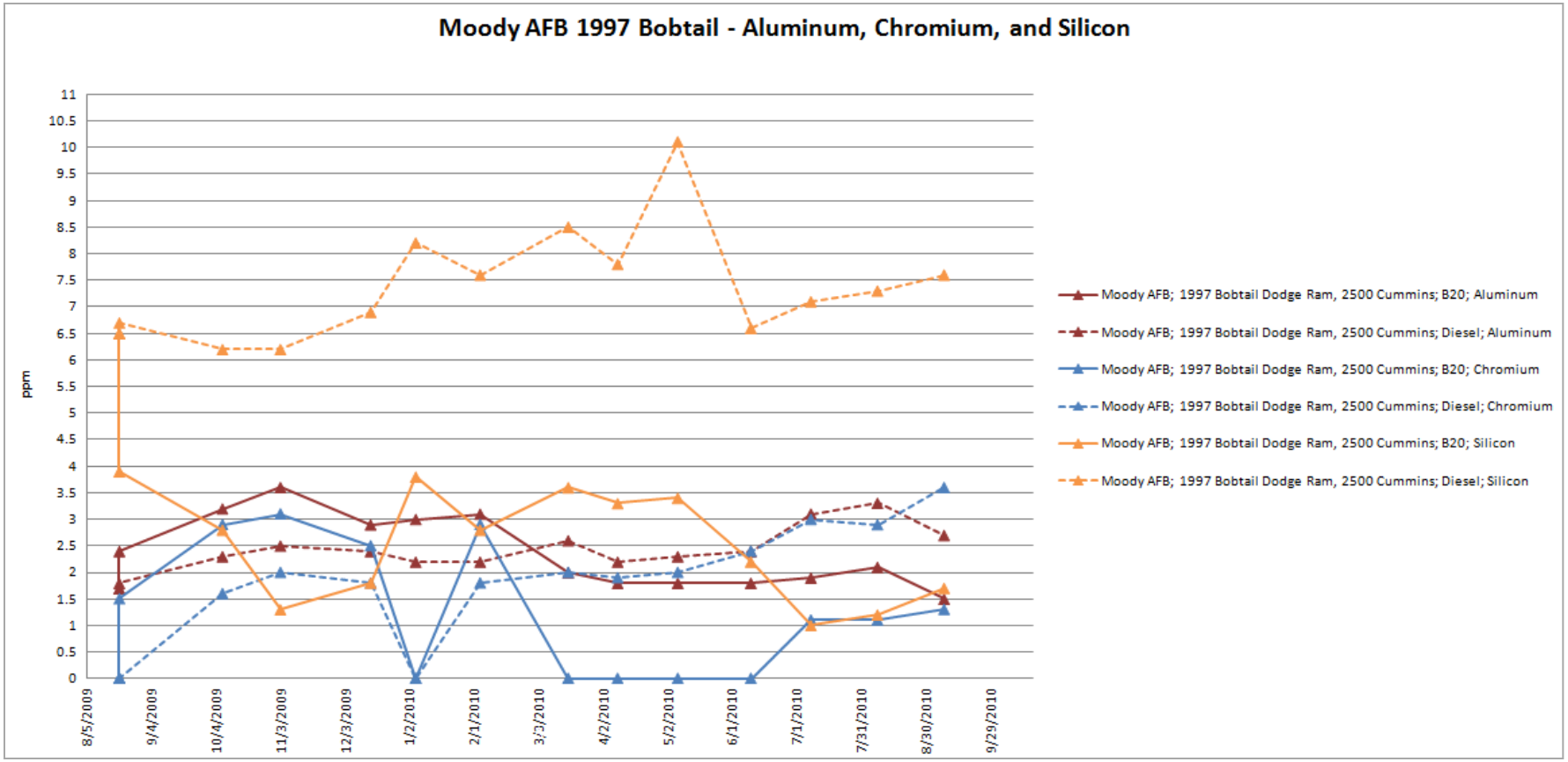
All results were less than 0.1% water, with the exception of two vehicle samples from Moody AFB.

JOAP Oil Test Results



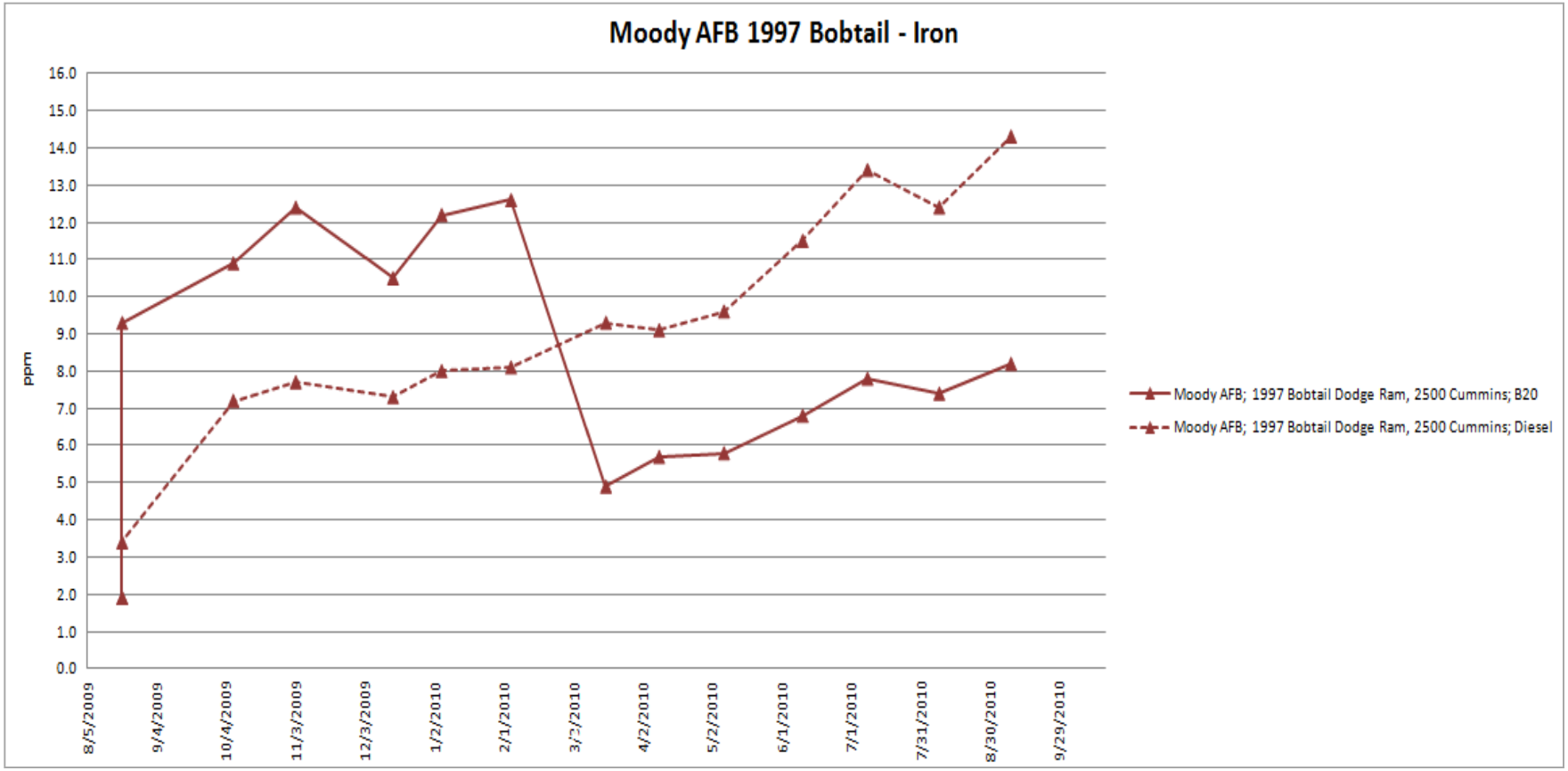
No significant difference between test and control vehicles.

JOAP Oil Test Results



No significant difference between test and control vehicles.

JOAP Oil Test Results



No significant difference between test and control vehicles.